



US009409790B2

(12) **United States Patent**
Nishino et al.

(10) **Patent No.:** **US 9,409,790 B2**
(45) **Date of Patent:** ***Aug. 9, 2016**

(54) **TITANIUM OXIDE STRUCTURE AND
POROUS TITANIUM OXIDE COMPOSITION**

(75) Inventors: **Hitoshi Nishino**, Osaka (JP); **Ryoichi Nishida**, Osaka (JP); **Hiroaki Matsuyoshi**, Osaka (JP); **Hiroki Sakamoto**, Osaka (JP); **Haruo Tomita**, Osaka (JP); **Hidekazu Hayama**, Kyoto (JP); **Minoru Tabuchi**, Kyoto (JP); **Nobuko Ichimura**, Kyoto (JP); **Tomoe Deguchi**, Kyoto (JP)

(73) Assignee: **OSAKA GAS CO., LTD.**, Osaka-shi, Osaka (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 813 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **12/996,546**

(22) PCT Filed: **Jun. 19, 2009**

(86) PCT No.: **PCT/JP2009/061220**
§ 371 (c)(1),
(2), (4) Date: **Dec. 6, 2010**

(87) PCT Pub. No.: **WO2009/154274**
PCT Pub. Date: **Dec. 23, 2009**

(65) **Prior Publication Data**
US 2011/0079276 A1 Apr. 7, 2011

(30) **Foreign Application Priority Data**
Jun. 20, 2008 (JP) 2008-162428
Jun. 20, 2008 (JP) 2008-162450

(51) **Int. Cl.**
H01L 51/46 (2006.01)
C01G 23/04 (2006.01)

(Continued)

(52) **U.S. Cl.**
CPC **C01G 23/04** (2013.01); **B82Y 30/00** (2013.01); **C01G 23/047** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01L 31/0232; H01L 31/0522; H01L 31/0527; H01L 33/60; Y02E 10/52; H01G 9/2031; Y10S 264/39
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,350,644 A 9/1994 Graetzel et al.
6,027,775 A 2/2000 Kasuga et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CN 1498440 A 5/2004
JP 8-015097 A 1/1996

(Continued)

OTHER PUBLICATIONS

Hoyer, Formation of a Titanium Dioxide Nanotube Array, *Langmuir*, pp. 1411-1413 (1996).*

(Continued)

Primary Examiner — Jayne Mershon

(74) *Attorney, Agent, or Firm* — Westerman, Hattori, Daniels & Adrian, LLP

(57) **ABSTRACT**

With a view to realizing a titanium oxide structure that has a large surface area and enables efficient transfer of ions and electrons by virtue of titanium oxide particles connected to one another, an object of the invention is to develop a material useful as an active material for dye-sensitized solar cells, and a process for producing the material; a porous titanium oxide composition and a process for producing the composition; and a photoelectric conversion element comprising the titanium oxide structure or porous titanium oxide composition.

15 Claims, 10 Drawing Sheets

